Title: Impact!!!

A math and physical science lesson investigating the relationships between mass, force, and acceleration as stated in Newton's Second Law of Motion.

Link to Outcomes:

Mathematics Outcomes

- **Problem Solving** Students will demonstrate their ability to solve problems using data gathered in a science experiment.
- **Communication** Students will express in writing conclusions based on observations and data collected in the investigations.
- **Reasoning** Students will use data to make and test hypotheses.
- **Connections** Students will demonstrate connections between concepts from the disciplines of mathematics and science.
- **Algebra** Students will use equations and algebraic expressions to represent situations that involve variable quantities.
- **Functions** Students will represent, analyze and interpret relationships using tables, formulas, equations and graphs.
- **Statistics** Students will use curve fitting to predict from data.

Science Outcomes

- **Processes of Science** Student will demonstrate the ability to use the scientific processes of generating hypotheses, collecting and interpreting data, and predicting consequences.
- **Communications** Students will communicate about science both in oral and written form.
- **Applications** Students will apply scientific and technical knowledge to understand and attack authentic problems from everyday life.
- **Habits of Mind** Student will exhibit healthy skepticism toward conclusions coupled with the willingness to change views in the face of solid evidence.

Brief Overview:

Students will gather data in an experiment in order to investigate Newton's Second Law of Motion, force = mass x acceleration. They will perform two investigations. Acceleration will be measured on a laboratory cart of constant mass while force propelling the cart is varied. In the second investigation, acceleration will again be determined but force applied to the cart will be held constant while the mass of the cart is varied. Students will analyze motion graphs, use the data to determine acceleration for each trial and draw graphs of the relationships in the two investigations. Students will use this information to predict variables affecting a car crash.

Grade/Level:

Grades 8 – 12; Algebra I

Duration/Length:

Two 45-minute class periods

Prerequisite Knowledge:

- Plot points on a graph, read and interpret a graph
- Evaluate an algebraic expression
- Understand that velocity (distance/time) and acceleration (velocity/time) are rates of change.

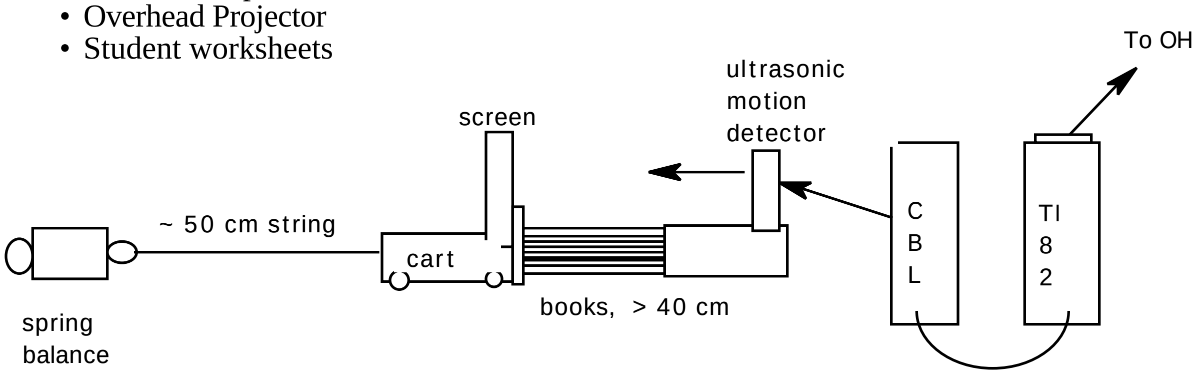
Objectives:

Students will…

- construct, analyze, interpret, graphs.
- discover the relationship between force, mass and acceleration through gathering data in a laboratory activity.
- predict effects of changing force or mass on acceleration.
- work in a whole group setting, with assigned roles dividing up the overall investigation into parts.
- apply what they have learned to a car crash situation.

Materials/Resources/Printed Materials:

- TI-82 Graphics Calculator with overhead projection device and unit to unit link cable
- Calculator Based Laboratory (CBL) with MOTION and PLOTS software, Ultrasonic motion detector
- Laboratory carts, cardboard, tape, spring balance in Newtons, 50 cm string attached to cart with loop at other end, masses
- Overhead Projector
- Student worksheets



Development/Procedures:

Lab set up (before class)

1. Set up spring balance, string, cart (with box or cardboard screen), and books as in diagram above.

2. Clear the TI-82 calculator in three places: {Y=}, STAT PLOT (Plots Off), {STAT} (Lists).

3. Connect the CBL unit to the TI-82 calculator with the unit-to-unit link cable using the I/O ports located on the bottom edge of each unit.

4. Press the cable ends in firmly.

5. Connect the motion detector to SONIC port on the left side of the CBL unit.

6. Turn on the CBL unit and the calculator.

7. Be sure motion detector is more than 40 cm from starting point of cart.

Lab Introduction

1. Ask students to hypothesize which would create a greater impact in a crash, a cement truck or a Corvette? Tally votes for cement truck, Corvette, or "more information needed." Ask students in third group what further information they might need.

2. Show students the equipment, explaining how it is going to be used.

3. Assign roles to students:
    A) Operate TI-82. (one)
    B) Operate spring cart. (one)
    C) Read velocity and times from TI-82 overhead. (one)
    D) Write results on chalkboard data table. (one)
    E) Monitor spring cart for proper use. (class)
    F) Calculate accelerations from data table. (1 small group per data set)

Lab Activity

Part A — (Vary force, measure acceleration, mass constant)

1. Cart Operator connects spring balance to cart and practices holding the cart in place while pulling back on spring scale until it registers 4N of force. Then release the cart, being careful not to pull the cart by the spring scale. Cart Operator should try this with different forces The class should observe that the motion is unhindered and in a straight line.

2. Cart Operator sets spring scale to 4N, holding the spring cart at starting line. He/she calls out "cart ready."

3. TI-82 Operator starts the MOTION program ({PRGM}, {G} Motion, {ENTER}, {ENTER}) on the calculator.

    The screen will say   Enter collection time in seconds?
    Type: 5   Enter
    Press Enter to begin data collection. (Call out "Program Start")

4. Cart Operator says "one thousand one" for a one-second delay time. He/she then releases the cart.

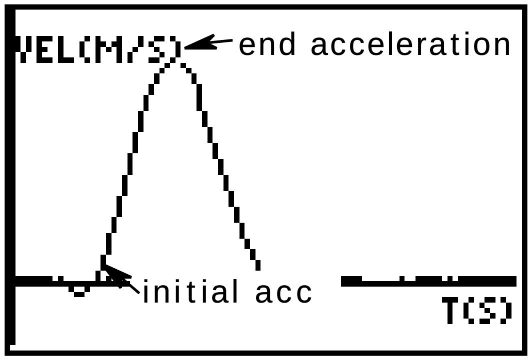
The sequence of calls will be	
• TI-Operator	"Program Ready"
• Cart Operator	"Cart set"
• TI-Operator	"Program start"
• Cart Operator	"one thousand and one" then release cart

5. Class observes motion of cart and decides if it is unhindered. Redo as needed.

6. Wait until data collection is complete and Plot Options screen is on TI-82.

7. TI-82 Operator presses {2} (Velocity -Time)

8. The graph will then appear. Interpret the motion graph with the class, and determine where the cart's positive acceleration begins and ends.



9. TI-Operator uses TRACE to move along the velocity-time plot. Identify the coordinates where the acceleration starts, using the first positive velocity. Reader calls out the initial time (x-coordinate) and the initial velocity (y-coordinate). Recorder writes these results on the chalkboard data table. The rest of the class writes these values on their worksheet data tables. Repeat for end acceleration having Reader call out final time and final velocity, Recorder writing on board, and class recording on data table.

10. Repeat steps 2 – 9 using 8N, 12N, 16N, and 20N .

11. Student will determine acceleration for each force measurement, using the formula on the worksheet. Each of five groups will determine acceleration for one of the five force readings. Students in each group will compare results for accuracy. One student from each group will enter acceleration result on the chalkboard data table. Students will record results on worksheet data table.

12. Review results for trends and possible errors in collecting or calculating data. Redo as needed.

13. Students will graph force (independent variable) on the x-axis and acceleration (dependent variable) on the y-axis, using the coordinate system on the worksheet. Title the graph Acceleration as a Function of Force. (See example in Part B)

14. Students will graph a line of best fit. This can be an approximation.

15. Person B can graph data on TI-82. **(Optional)**

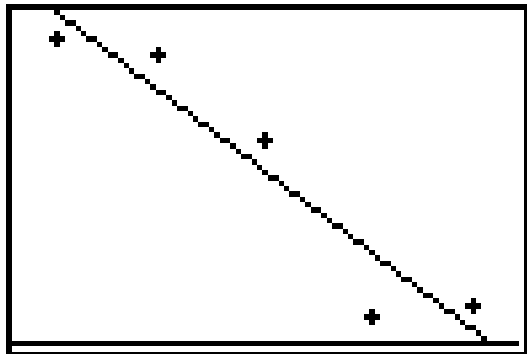
[STAT] [ENTER]
Input Force values in L_1
Input Acceleration values in L_2
[STAT] ❑ CALC ❑ (Set-up)
Check that **2-Var** Stats is set for Xlist: L_1 and Ylist: L_2
[2nd] STAT PLOT [ENTER] [ENTER] to highlight ON for Plot 1
Check description. Type: (scatter plat), Xlist: L,, Ylist: L_2, Mark: box
[Y=] [VARS] ❑ (Statistics) ❑ [▸] to highlight EQ ❑ (RegEQ)
(This puts your equation in Y 1=)
[STAT] ❑ CALC 5:LinReg [2nd] L1, [2nd] L2 [ENTER]
[ZOOM] 9:Zoomstat

Part B — (Vary mass, measure acceleration, force constant)

1. With a balance, determine the mass of the cart and record on Part B data sheet.
2. Cart Operator will set up equipment as in part A, except holding force at a constant 16N for each trial. In the first trial, no mass will be added to the cart. Cart Operator calls out "Cart ready."
3. Repeat steps 3 – 9 from Part A, having the students enter data in Part B data table.
4. Repeat steps 1 and 2 above using masses ranging from ½ the mass of the cart to twice the mass of the cart.
5. Repeat steps 11 and 12 from Part A
6. Students will graph mass (independent variable) on the x-axis and acceleration (dependent variable) on the y-axis, using the coordinate system on the worksheet. Title the graph Acceleration as a Function of Mass.

Title: Acceleration as a function of Mass

Acceleration



Mass

7. Person B will graph data in TI-82 as in step 14 from Part A.

Lab Conclusion

1. Discuss data and graphs with class, comparing them with observations. Teacher led questions could include:

   - Why does graph B have a negative slope?
   - What does this mean? Is this consistent with what you observed?
   - What happens to the acceleration of the cart as mass increases on the cart?
   - Would you expect a large mass vehicle such as a cement truck to have a large or small acceleration? How about a low mass vehicle such as a Corvette?
   - How would these factors effect the force of the vehicle in a car crash?

2. Distribute conclusion worksheet.

Evaluation:

Student evaluation will be based on worksheet completion and teacher observation of student participation during lab activity.

Extension/Follow Up:

Students will determine the y-intercept of the part B graph and from that will determine the mass of the laboratory cart used in the experiment.

Students will determine the accelerations needed to create equal forces in a crash for the 20,000 kg cement truck and the 1000 kg Corvette.

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References

Brueningsen, Chris and Krawiec, Wesley. *Exploring Physics and Math with the CBL System*. Texas Instruments Inc. 1994.

IMPACT !!! Name________________________

Objective: Investigate Newton's Second Law of Motion Pd_____Date_______

Data: Part A — (Hold mass constant, vary force, measure acceleration.)

Force (N)	T_i (sec)	V_i (m/sec)	T_f (sec)	V_f (m/sec)	Acceleration (m/sec/sec)
4 N					
8 N					
12 N					
16 N					
20 N					

$$\text{acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{final time} - \text{initial time}} = \frac{V_f - V_i}{T_f - T_i}$$

Show work here for ______ Newton Force

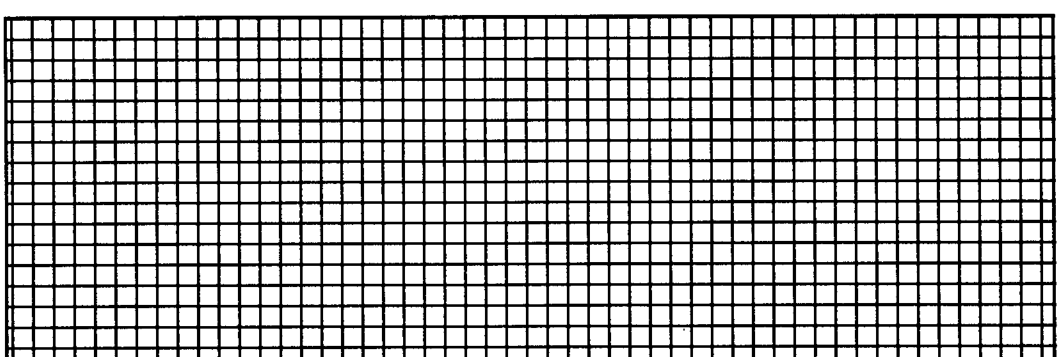
Substitute:

Simplify:

Answer with units: ____________

Graph: Part A Title: ________________________________

Acceleration (m/sec/sec)



Force (N)

IMPACT !!! Name____________________________

Objective: Investigate Newton's Second Law of Motion Pd_____Date_______

Data: Part B — (Hold force constant, vary mass, measure acceleration.)

Mass (N)	T_i (sec)	V_i (m/sec)	T_f (sec)	V_f (m/sec)	Acceleration (m/sec/sec)
Mass of Cart _______					
Mass of Cart +___g = ___g					
Mass of Cart +___g = ___g					
Mass of Cart +___g = ___g					
Mass of Cart +___g = ___g					

$$\text{acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{final time} - \text{initial time}} = \frac{V_f - V_i}{T_f - T_i}$$

Show work here for ______ Newton Force

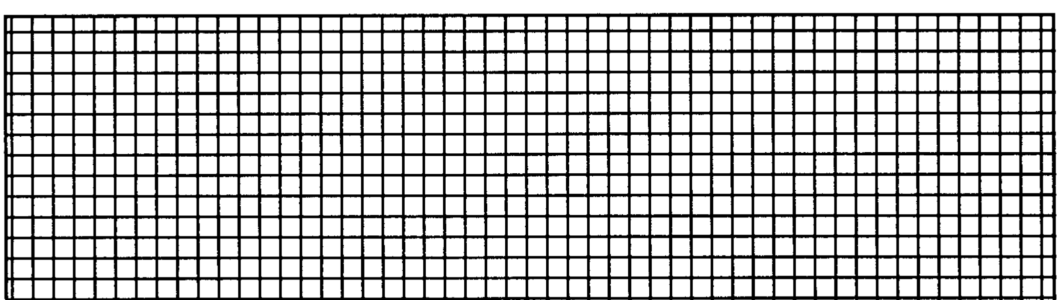
Substitute:

Simplify:

Answer with units: ____________

Graph: Part B Title: ________________________________

Acceleration (m/sec/sec)



Mass (N)

IMPACT!!! Name___________________________

Conclusion: Pd______ Date__________

Using the graph from Part A :

1. What happened to acceleration as the force was increased?

2. Describe the relationship between force and acceleration.

3. Is this a positive or negative relationship? _______________

4. Predict the acceleration of the cart for a force of 10N.____________________

5. Predict the force needed to produce an acceleration of _______m/sec/sec._____________

6. How would replacing a car's engine with a more powerful engine affect the car's acceleration?

Using the graph from Part B :

1. What happened to acceleration as the mass was increased?

2. Describe the relationship between mass and acceleration.

3. Is this a positive or negative relationship? ________________.

4. Estimate the acceleration of the cart for a mass of 250g.____________________.

5. Predict the acceleration of the cart for a mass of 600g.____________________.

6. Estimate the mass needed to produce an acceleration of _______m/sec/sec._____________.

IMPACT!!!
Conclusion (cont.):

7. Newton's Second Law of Motion states Force = Mass x Acceleration. Use this formula to determine the following:
   (Note: Newton (N) is a unit of force N = Kg • m/sec/sec)

   a. What is the force produced by a 20,000 kg cement truck accelerating at 0.2 m/sec/sec?

   b. What is the force produced by a 1000 kg Corvette accelerating at 5m/sec/sec?

   c. Which of the vehicles in these examples would produce the greater force (impact) in a crash? cement truck or Corvette (Use answers from 7a and 7b).

   d. If the cement truck and the Corvette had the same acceleration, would you expect the same result? (Y / N) Explain.

8. Describe <u>in paragraph form</u> the conditions affecting the amount of force in a crash.